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INFLUENCE

W H I C H

**Two Pendulum Clocks**

Were observed to have upon each other.

Communicated to the

**ROYAL SOCIETY**

B Y

**JOHN ELLICOTT, F.R.S.**



*An Account of the Influence which two Pendulum Clocks were observed to have upon each other.*

THE two Clocks upon which the following Observations were made, being designed for Regulators, particular Care was taken to have every Part made with all possible Exactness : The two Pendulums were hung in a manner different from what is usual ; and so disposed, that the Wheels might act upon them with more Advantage. Upon Trial they were found not only to move with greater Freedom than common, but an heavier Pendulum was kept in Motion by a smaller Weight. They were in every respect made as near alike as possible. The Ball of each of the Pendulums weighed above 23 lbs ; and required to be moved about 10° 5' from the Perpendicular, before the Teeth of the swing Wheel would scape free of the Pallets ; that is, before the Clocks would be set a going. The Weight to each was 3 lbs, which would cause either of the Pendulums in their Vibrations to describe an Arch of 30°. The two Clocks were each in Cases, which shut very close, and placed Sideways to one another, so near that when the Pendulums were at Rest, they were little more than about two Feet asunder. The odd Phænomena observed in them were these : In less than two Hours after they were set a going, one of them (which I call N<sup>o</sup> 1.) was found to stop ; and when set a going again, (as it was several times)

would never continue going two Hours together. As it had always kept going with great Freedom, before the other Clock (which I call N° 2.) was placed near it, this led me to conceive its stopping must be owing to some Influence the Motion of one of the Pendulums had upon the other; and upon watching them more narrowly, I found the Motion of N° 2. to increase as N° 1. diminished; and at the time N° 1. stopped, N° 2. described an Arch of  $5^{\circ}$ , that is nearly two Degrees more than it would have done, if the other had not been near it, and more than it did move in a short time after the other Pendulum came to be at Rest: This made me imagine that they had a mutual Influence upon each other. Upon this I stopped the Pendulum of N° 2. leaving it quite at Rest, and set N° 1. a going, the Pendulum describing as large an Arch as the Case would permit, *viz.* about  $5^{\circ}$ . In about 20 Minutes after, I went to observe whether there was any Motion communicated to the Pendulum N° 2. when, to my Surprize, I found the Clock going, and the Pendulum to describe an Arch of  $3^{\circ}$ , whereas at the same time N° 1. did not move  $40'$ . In about half an Hour after, N° 1. stopped, and the Motion of N° 2. was increased to very near  $5^{\circ}$ . I then stopped N° 2. a second time, and set N° 1. a going, as before; and standing to observe them, I presently found the Pendulum of N° 2. to begin to move, and the Motion to increase gradually, till in  $17' 40''$  it described an Arch of  $2^{\circ} 10'$ , at which time the Wheel discharging itself of the Pallets, the Clock went: The Arches of the Vibrations continued to increase, till (as in the former Experiment) the Pendulum moved  $5^{\circ}$ ; the Motion

Motion of the Pendulum N<sup>o</sup> 1. gradually decreasing all the while, as the other increased; and in three Quarters of an Hour after, it stopped. I then left the Pendulum of N<sup>o</sup> 1. at Rest, and set N<sup>o</sup> 2. a going, making it describe an Arch of 5°; it continued to vibrate less and less, till it described but about 3°; in which Arch it continued to move all the time I observed it, which was several Hours. The Pendulum of N<sup>o</sup> 1. seemed but little affected by the Motion of N<sup>o</sup> 2. I tried these Experiments several times over, without finding any remarkable Difference. The freer the Room was from any Motion (as Peoples walking about in it, &c.) I found the Experiments to succeed the better; and once I found N<sup>o</sup> 2. set a going in 16' 20", and N<sup>o</sup> 1. at that time stopped in 36' 40".

I shall not offer my Opinion to this Honourable Society, concerning the Cause of these *Phænomena*, or at least not till I have farther examined it by the Help of some more Observations and Experiments.

### *Further Observations and Experiments concerning the two Clocks above-mentioned.*

**I**N the preceding Paper I had the Pleasure to communicate to this Honourable Society, an Account of the extraordinary Influence I observed two Clocks to have upon each other, and which was attended with such Circumstances, as I believe had never before been taken Notice of. I shall now beg Leave to lay before you some farther Observations

I have since made, which will, I hope, in great measure, account for the Facts then related.

In my former Account I took Notice, that the two Clocks were in separate Cases, and that the Backs of them rested against the same Rail; that the Pendulums, when at Rest, were about two Feet asunder, and weighed about 23 lb each, and were made to move with such Freedom, that a Weight of 3 lb. would cause either of the Pendulums to describe an Arch of three Degrees. The most remarkable Particulars then observed in them were these: If the Pendulum of one of the Clocks, which (for Distinction sake) I called N<sup>o</sup> 2. was left at Rest, and that of the other, which I called N<sup>o</sup> 1. was set a going, this would, in about 16 Minutes, communicate so great a Quantity of Motion to N<sup>o</sup> 2. as would make its Pendulum describe an Arch of above two Degrees, and would set the Work a going: That the Motion of the Pendulum of N<sup>o</sup> 1. constantly decreased as that of N<sup>o</sup> 2. increased, and after about 30 Minutes it did not describe an Arch sufficient to free the Teeth of the Wheel from the Pallets, so that the Clock stopped. At the same time the Pendulum of N<sup>o</sup> 2. described an Arch of five Degrees, which was two Degrees more than it would have done, had it not been affected by the Motion of N<sup>o</sup> 1. Upon leaving the Pendulum of N<sup>o</sup> 1. at Rest, and setting N<sup>o</sup> 2. a going, the Pendulum of N<sup>o</sup> 1. was found to be but little affected, and never moved sufficiently to set the Work a going. These seemingly different Effects, which the two Clocks had upon each other, I shall now endeavour to account for.

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The Manner in which the Motion is communicated to the Pendulum at Rest, I conceive to be thus : As the Pendulums are very heavy, when either of them is set a going, it occasions by its Vibrations a very small Motion, not only in the Case the Clock is fixed in, but, in a greater or lesser Degree, in every thing it touches ; and this Motion is communicated to the other Clock, by means of the Rail, against which both the Cases bear. The Motion thus communicated, which is too small to be discovered but by means of some such-like Experiments as these, will, I doubt not, be judged by many, insufficient to make so heavy a Pendulum describe an Arch of two Degrees, or large enough to set the Work a going ; and indeed it would be so, but for the very great Freedom with which the Pendulum is made to move, arising from the Manner in which it is hung. This appears from the very small Weight required to keep it going, which, when the Clock was first put together, was little more than one  $\frac{1}{16}$ . And if the Weight was taken off, and the Pendulum made to swing two Degrees, it would make 1200 Vibrations before it decreased half a Degree, so that it would not lose the  $\frac{1}{3000}$  part of an Inch in each Vibration. Indeed if the Weight was hung on, the Friction would be increased, and the Pendulum would not move quite so freely ; but even in that Case it was found to lose but little more than the  $\frac{1}{2000}$  part of an Inch, or about three Seconds of a Degree, in one Vibration ; and therefore if the Motion communicated to it from the other, will make it describe an Arch exceeding three Seconds, the Vibrations must continually increase till the Work is set a going.

And

And that the Motion is communicated in the manner above supposed, is confirmed by the following Experiments:

A Prop was set against the Back of the Case of N° 2. to prevent its bearing against the Rail; and N° 1. was set a going; then observing them for several Hours, I could not perceive the least Motion communicated to N° 2. I then set both the Clocks a going, and they continued going several Days; but I could not find they had any Influence upon each other. Instead of the Prop against the Back of the Case, I put Wedges under the Bottoms of both the Cases, to prevent their bearing against the Rail; and stuck a Piece of Wood between them, just tight enough to support its own Weight. Then setting N° 1. a going, I found the Influence so much increased, that N° 2. was set a going in less than six Minutes, and N° 1. stopped in about six Minutes after. In order to try what Difference would arise, if the Clocks were fixed on a more solid Floor, I placed them (exactly in the same manner as in the last Experiment) upon the Stone Pavement under the Piazza's of the *Royal Exchange*, and stuck the Piece of Wood between them, as before; and setting N° 1. a going, the only Difference I could perceive, was, that it was 15 Minutes before N° 2. was set a going, and N° 1. continued going near half an Hour before it stopped. From these Experiments I think it plainly appears, that the Pendulum which is put in Motion, as it moves towards either side of the Case, makes the Pressure upon the Feet of the Case to be unequal, and, by its Weight, occasions a small Bearing or Motion in the Case on that Side towards which the Pen-

Pendulum is moving; and which, by the Interposition of any solid Body, will be communicated to the other Clock, whose Pendulum was left at Rest. The only Objection to this, I conceive, is the different Effects which the two Pendulums seemed to have upon each other. But this I hope to explain to Satisfaction.

For, notwithstanding these different Effects, I soon found, by several Experiments, that the two Clocks mutually affected each other, and in the same Manner, though not with equal Force; and that the Varieties observed in their Actions upon each other, arose from the unequal Lengths of their Pendulums only.

For, upon moving one of the Clocks to another Part of the Room, and setting them both a going, I found that N° 2. gained of N° 1. about one Minute 36 Seconds in 24 Hours. Then fixing both against the Rail, as at first, I set them a going, and made the Pendulums to vibrate about four Degrees; but I soon observed that of N° 1. to increase, and that of N° 2. to decrease; and in a short time it did not describe an Arch large enough to keep the Wheels in Motion. In a little time after it began to increase again, and in a few Minutes it described an Arch of two Degrees, and the Clock went. Its Vibrations continued to increase for a considerable time, but it never vibrated four Degrees, as when first set a going. Whilst the Vibrations of N° 2. increased, those of N° 1. decreased, till the Clock stopped, and the Pendulum did not describe an Arch of more than one Degree 30 Minutes. It then began to increase again, and N° 2. decreased, and stopped a second time, but

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was set a going again, as before. After this N° 1. stopped a second time, and the Vibrations continued to decrease till the Pendulum was almost at Rest. It afterwards increased a small matter, but not sufficiently to set the Work a going. But N° 2. continued going, its Pendulum describing an Arch of about three Degrees.

Finding them to act thus *mutually* and *alternately* upon each other, I set them both a going a second time, and made the Pendulums describe as large Arches as the Cases would permit. During this Experiment, as in the former, I sometimes found the one, and at other times the contrary Pendulum to make the largest Vibrations. But as they had so large a Quantity of Motion given them at first, neither of them lost so much during the Period it was acted upon by the other, as to have its Work stopped, but both continued going for several Days without varying one Second from each other; though when at a Distance, as was before observed, they varied one Minute 36 Seconds in 24 Hours. Whilst they continued thus going together, I compared them with a third Clock, and found that N° 1. went one Minute 17 Seconds faster, and N° 2. 19 Seconds slower, than they did when placed at a Distance, so as to have no Influence upon each other.

Upon altering the Lengths of the Pendulums, I found the Period in which their Motions increased and decreased, by their mutual Action upon each other, was changed; and would be prolonged as the Pendulums came nearer to an Equality, which from the Nature of the Action it was reasonable to expect it would. This discovers the Reason why the Pendulum

dulum of N° 2. when left at Rest, would be set a going by the Motion of N° 1. whereas if N° 1. was left at Rest, it would not be set a going again by the Motion of N° 2.

For I found by several Experiments, that the same Pendulum, when kept in Motion by a Weight, would go faster, than when it only moved by its own Gravity. On this Principle, which may easily be accounted for, it follows, that during the Time in which the shortest Pendulum, N° 2. was only acted upon by N° 1. it would move slower, and the Times of its Vibrations approach nearer to an Equality with those of N° 1. than after it came to be kept in Motion by the Weight; and by this means the Time which N° 1. would continue to act upon it, would be prolonged, and be more than was required to make the Pendulum describe an Arch sufficient to set the Work a going. But on the contrary, while the Pendulum of N° 1. which was the longest, was only acted upon by N° 2. as it would move slower, the Difference of the Times of the Vibrations would be increased; and consequently the Time which N° 2. would continue to act upon it, would for this Cause be shortened, so that before the Pendulum of N° 1. would describe an Arch sufficient to set the Work a going, the Period of its being acted upon would be ended, and it would begin to act upon N° 2. at which time its Vibrations would immediately decrease, and continue to do so till it came to be almost at Rest. And thus it would continue sometimes to move more, and at other times less, but never sufficiently to set the Clock a going.

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This Account might be confirmed by many more Experiments I have made relating to this Subject; but as I hope these already mentioned will be thought sufficient to confirm the Truth of what I have advanced, I shall forbear to trespass any longer on your Time, and subscribe myself

*Your most obedient  
Humble Servant,*

John Ellicott.



